External Peer Review

SARC 63

63rd Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) Benchmark stock assessment for Ocean quahog

North East Fisheries Science Center, Woods Hole, Massachusetts
February 21 – 23, 2017

Report to Center for Independent Experts

Michael C. Bell
International Centre for Island Technology
Heriot-Watt University
School of Energy, Geoscience, Infrastructure and Society
Old Academy
Back Road
Stromness
Orkney KW16 3AW
UK
M.C.Bell@hw.ac.uk

Contents

Executive summary

- This report is a peer review of the benchmark assessment for ocean quahog presented at the SARC-63 Review in February 2017.
- Ocean quahog landings data are considered to be accurate because of the cage-tagging system. The assessment reports data on commercial landings, effort and catch composition for 1982-2016. Adjustments are made for incidental mortality in the ocean quahog fishery and discard mortality in the Atlantic surfclam fishery. Assumptions about these are not thought to have a significant impact on the assessment, but it will be worth re-consideration in the light of increasing overlap of the surfclam distribution and a possible recruitment pulse in the ocean quahog stock.
- The distribution of the fishery has moved northwards during the assessed period, and this pattern has been accompanied by declines in LPUE in southern areas. Owing to the small scale of the fishery with respect to the stock, this is considered to be a shift of the fishery in response to changing stock conditions rather than indicative of a fishery-driven stock decline.
- Fishery-independent surveys provide an important source of information on trends in stock abundance. This is complicated by the use of two non-overlapping surveys differing in gear performance, but characterization of catchability provides important priors for informing the scale of abundance estimated in the analytical assessment model.
- Ocean quahog distribution has not changed significantly over time, increasing overlap with Atlantic surfclams being due to a shift in the deep water stock boundary in the latter species. Modelling of survey data in relation to habitat variables provides a good basis for predicting the distribution of ocean quahog habitat defined in terms of climatology, temperature, bottom type and topography, and ocean productivity.
- Analytical assessments were undertaken using the Stock Synthesis III (SS3) integrated model framework, incorporating commercial and survey catch data and length compositions together with information on growth and natural mortality and priors for survey catchability. Despite uncertainties about the scale of stock biomass, model outcomes provide a good basis for inferences about stock biomass and fishing mortality. The model considered two stock areas, these being Georges Bank and all regions to the south. This benchmark assessment replaces the previous delay difference model (KLAMZ).
- Management strategy evaluations (MSE) based on the SS3 model provide the basis for recommended new reference points. This represents a big improvement on the previous reference points which were based on a finfish proxy and treatment of an estimate of fishable biomass in 1978 as an estimate of unfished stock biomass. The new proposed threshold for fishing mortality is based on a value that provides consistently high yields and few years of fishery closure across a range of scenarios and uncertainties. Biomass reference points are based on direct estimation of unfished spawning stock biomass from the SS3 model.
- It is convincingly demonstrated that the ocean quahog is not overfished and is not experiencing overfishing. Comprehensive stock projections show that the probability of the stock becoming overfished over the next 50 years is effectively zero, even in the event that there is no recruitment over this period. This is a consequence of high stock biomass and very low levels of both natural and fishing mortality.
- This benchmark assessment of ocean quahog provides a sound scientific basis for fishery management.

- Progress against existing research recommendations is reviewed, and recommendations for future research are made.

Recommendations

- Population dynamic processes in ocean quahog are likely to occur at smaller spatial scales than considered in the assessment. It is recommended that there be analysis of survey data to identify meaningful spatial scales of variability and to consider implications of assessing the stock at larger spatial scales. Such analyses might include geostatistical approaches and empirical analysis of local recruitment and mortality trends.
- Optimal design and frequency of surveys for ocean quahogs should be examined, considering the possibility of re-stratification of historical data. Spatial analyses should be used to inform this process, and the use of fixed survey stations to follow population dynamics over time should be considered. Fixed survey stations potentially could be used in place of the current semi-random component of surveys. Survey frequency should be considered in relation to the time-scales of ocean quahog dynamics, considering the potential trade-off between loss of information from increased survey intervals and gains in precision and coverage from greater survey intensity.
- There should be investigations of possible variability in indirect fishing mortality in the ocean quahog fishery and in discard mortality in the Atlantic surfclam fishery. This needs to take account the possible changes in length composition available to the fishery if the late 1990s recruitment pulse proves to be real, and the shift in surfclam distribution towards greater overlap with the ocean quahog stock.
- Model-based imputation should be further considered as an alternative to the ad hoc data 'borrowing' used to fill missing strata in the survey data. This should be examined in the light of changes in survey design which may either change or obviate the need for filling gaps. Geostatistical approaches to survey data analysis should also be considered as an alternative to the current methodology.
- There should be further examination of the drivers for decline in ocean quahog stocks in the southern regions. This needs to be undertaken in the context of habitat modelling and spatial scales of variability.
- Regional and other differences in productivity should be examined in relation to age determination and growth, with consideration of the implications of this for spatial patterns in the stock and fishery. This could usefully be accompanied by analysis of historic growth patterns in relation to drivers related to indices such as sea surface temperature and the North Atlantic Oscillation.
- Implementation of more flexible growth models should be sought for the SS3 framework. This should include the Tanaka model.
- Future stock assessment reports should include an appendix setting out the details of the equations used to describe population dynamics in the analytical assessment model and of how the different data sources contribute to the calculation of the overall model likelihood. There should also be an account of the steps taken in deriving the final model adopted for the assessment. If possible, reporting of uncertainty around model outputs should be based on MCMC.

- It is recommended that allocation of recruitment to northern and southern stock areas should be based on the distribution of proportions estimated in the assessed period rather than just that of the final year.
- The Working Group should have further discussions about research priorities based on the prioritized list provided by Larry Jacobson at the end of the SARC 63 review.

Background

The purpose of SARC-63 is to provide an external peer review of a benchmark stock assessment for ocean surfclam (*Arctica islandica*). The species is a large bivalve of extreme longevity (500 years), distributed widely in the North Atlantic from the Arctic down to Cape Hatteras on the east coast of the USA. It is found primarily in depths 20-80 m in US waters and is the target of a dredge fishery in the US EEZ extending from Southern Virginia in the south to Georges Bank in the north, managed through an Individual Transferable Quota (ITQ) system. The fishery is assessed as two stocks, a southern stock including regions from Southern Virginia to Southern New England, and a northern stock comprising Georges Bank.

The ocean quahog stock assessment working group addressed nine Terms of Reference (TOR – see p.15) considering commercial and survey data, their incorporation into an analytical assessment model to estimate stock biomass and fishing mortality, the development of biological reference points, determination of stock status and projection of stock trends. Together, these aspects provide a scientific basis for management of the fishery. This report is my peer review of the assessment for the Center for Independent Experts (CIE), working to the Statement of Work set out in Appendix 2, p.18).

Description of review activities

Online access (http://www.nefsc.noaa.gov/SARC/SARC-63-pdfs/) to documents relating to SARC 63 was made available to reviewers about three weeks ahead of the review meeting (see bibliography of review material at Appendix 1, p.16). This included background material such as academic papers and previous ocean quahog assessment documents. The full stock assessment report and outputs from model runs were made available about two weeks prior to the meeting.

The review meeting took place at the Northeast Fisheries Science Center (NEFSC), Woods Hole, 21-23 February 2017 (see Agenda at Appendix 4, p.33), chaired by Ed Houde of the University of Maryland Center for Environmental Science (also a member of the Scientific and Statistical Committee of the Mid-Atlantic Fishery Management Council). The meeting was introduced and guided by Jim Weinberg (NEFSC) as the SAW Chair. Jim made clear that the standard against which the stock assessment work should be judged is its credibility as a scientific basis for management.

Following introductions, day 1 of the meeting (21 February) was taken up with a presentation of the stock assessment by Dan Hennen (NEFSC) as the assessment lead, covering all nine TORs, supported also by Larry Jacobson (NEFSC) as the Working Group Chair. Questions of clarification were dealt with during the presentation, with more substantive discussions at the end of each TOR. Public input was invited during these discussions, mainly in relation to clarification about supporting research (e.g., in relation to age determination), and there was a formal opportunity for public comment at the end of the day (one comment from Tom Alspach of Sea Watch International, querying some incorrect figures in a table of projected biomass).

Day 2 (22 February) commenced with responses by Dan Hennen to requests from the reviewers for additional analyses. These included a request for Markov Chain Monte Carlo (MCMC) runs to explore uncertainty in the assessment model outputs, corrections to projection tables and figures, a stock projection under a zero recruitment scenario, examining the effects on the assessment of removing an outlying survey data point (1994), and corrections to a table comparing current and recommended reference points. Following discussion on these tasks, the review panel convened a brief closed session to agree an overall response to the assessment and feedback was then provided to the meeting in plenary. The remainder of the day was taken up with editing the Assessment Summary Report in plenary.

Day 3 (23 February) was taken up mainly in drafting of the SARC Summary Report. The SARC Chair and CIE reviewers agreed summary points to be covered under each TOR. Writing tasks for each TOR were then allocated as follows:

- Ed Houde: TOR-1 (commercial catch)
- Michael Bell: TOR-3 (habitat), TOR-7 (stock status), TOR-9 (research recommendations)
- Martin Cryer: TOR-5 (analytical stock assessment model), TOR-6 (biological reference points)
- Anthony Hart: TOR-2 (survey), TOR-4 (biological parameters), TOR-8 (stock projections)

An almost complete draft of the SARC Summary Report was completed by the end of the day. The report was finalized by email exchange between SARC Panel members in the few days following the meeting, and at the time of writing (9 March) a near-final draft was ready for submission to the SAW Chair before 16 March.

My contributions to the review were to read all background material and working papers ahead of the meeting, to ask questions and participate fully in all discussions during the meeting, and to contribute to the drafting of the Assessment Summary Report and SARC Summary Report as detailed above. Consensus amongst the reviewers was not sought, but there was agreement between the reviewers about the main points, as reflected in the SARC Summary Report. I agree fully with the Summary Report; my individual report here amplifies my own views on the assessment.

Summary of findings

TOR-1 Commercial catch and effort data

Estimate catch from all sources including landings and discards. Map the spatial and temporal distribution of landings, discards, and fishing effort, as appropriate. Characterize the uncertainty in these sources of data.

This TOR was met in full. The assessment applies to the EEZ stock in a northern area (Georges Bank) and a southern area (Southern New England down to Cape Hatteras), but excludes the Maine mahogany ocean quahog fishery which is thought to be based on a biologically separate stock comprising less than 1% of the total stock in federal waters. Regional landings data were provided in the report for the period 1982-2016. In most, but not all, years during this period landings have been substantially less than the quota, this being due to market limitations rather than stock availability.

Marked changes have been seen in the distribution of the fishery since 1982, showing a distinct trend of moving northwards. After domination by Delmarva and New Jersey landings up to the late 1980s, the bulk of landings are now taken from Long Island and Southern New England. This shift has been accompanied by declines in commercial landings per unit effort in southern regions. The Panel accepted the Working Group view that this pattern is not a cause for concern in relation to serial depletion. Rather, the pattern appears to result from changes in stock distribution not related to fishing processes, probably stemming from temperature increases. A downward trend of landings since the early 1990s is a result of changes in market demand; industry representatives confirm that there is both fishery capacity and ocean quahog availability to support a larger fishery. Commercial catch rates are not considered to be indicative of overall stock trends, given targeting behavior of the vessels at much smaller spatial scales than the stock.

Although the Panel accepted the basis for the Working Group's lack of concern about the spatial patterns evident in the fishery, and that landings per unit effort is likely to be a poor index of abundance for the ocean quahog stock, it would be useful to see a comprehensive interpretation of these patterns in future assessment reports. This is consistent with my overall view that there is a need to understand ocean quahog population processes at much smaller spatial scales.

Landings are assumed to be accurate owing to the cage-tagging system. Given that landings are not constrained by the quota, there is no incentive to misrepresent catch. Although the assumption that landings are known without error is undoubtedly wrong to some degree, the landings data are nevertheless very good. The Panel accepted that errors relating to discarding in the surfclam fishery and to assumptions about incidental mortality in the ocean quahog fishery are unlikely to affect inferences about scale and trends in fishery removals of ocean quahog. I have two caveats to offer in relation to this conclusion:

(i) Given that there is a trend of increasing overlap of surfclam with the near-shore boundary of the ocean quahog stock, mixed catches in the surfclam fishery are likely to increase over time, and the consequences of this for additional mortality of ocean quahogs in the surfclam fishery should be carefully considered.

(ii) Given the possibility that there may have been a recruitment pulse of ocean quahogs in the late 1990s (based on size composition data interpreted through the medium of the analytical assessment model), the interaction of dredge selectivity with the size composition of the stock may change over time, hence the current adjustment of 5% by weight may no longer be justified. The implications of this change should be carefully examined, with more explicit accounting for selection at size made in any adjustment factor.

TOR-2 Survey indices and logbook data

Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). Use logbook data to investigate regional changes in LPUE, catch and effort. Characterize the uncertainty and any bias in these sources of data. Evaluate the spatial coverage, precision, and accuracy of the new clam survey.

This TOR was met in full. Analyses of logbook data and commercial LPUE were reported under TOR-1, and this section is focused on NEFSC clam surveys. These were a survey using a small research dredge (RD) conducted from 1982-2011 from the *RV Delaware II*, and a survey from 2012-2016 using a more efficient modified commercial dredge (MCD) deployed from the commercial vessel *ESS Pursuit*.

Interpretation of survey data in terms of stock trends is complicated by the discontinuity between the two surveys. The RD and MCD differ markedly in performance and selectivity, the latter having a much higher catchability and a selectivity curve shifted towards larger sizes of clam. Dredge performance was not discussed in detail during the review, but it is very apparent that there has been an impressive amount of effort at characterizing this for both RD and MCD, in terms of both field work and model development (patch model). This issue has been visited in previous reviews, including the recent SARC 61 review of the benchmark assessment for surfclam (NEFSC, 2016). My view is that the characterization of the dredge performance is as good as it possibly can be given available resources, although it is regrettable that there was no opportunity for comparative fishing to cross-calibrate the surveys. It is unlikely that issues such as changes in ocean quahog catchability between depletion fishing passes (owing to burrowing behavior and sediment removal) will satisfactorily be resolved, but I believe that the survey provides a very good basis for characterizing trends in stock abundance at both regional and overall levels. Caution in interpreting trends over the survey discontinuity is needed, and statements in the assessment report about recent trends of increase in the southern regions are unwarranted, although it is certainly true to say that there are regional differences in trend.

Surveys include ‘semi-random’ tows to cover important areas that would otherwise be missed by the stratified random sampling strategy. ‘Semi-random’ is effectively not random at all, and it can be argued that these tows should not be included in estimation of survey abundance. Panel discussion of this issue mirrors previous discussions in relation to surfclam surveys at SARC-61. Certainly, the effect of these semi-random tows on survey bias and precision needs to be explored, but I take the view that data from these tows could be very useful in analysis of spatial patterns. Plans for optimizing survey design for ocean quahogs, which presumably include post-stratification of data from previous surveys, could usefully address the issue of integrating the semi-random tows in a rigorous statistical framework, e.g., using geostatistical approaches. Abundance and composition (size-frequency) data from the surveys provide the opportunity for interpreting spatial patterns in terms of population dynamic processes at the ‘bed’ scale. As re-iterated at several points in this document, I believe that analysis of the interaction between the stock and the fishery needs to be underpinned by a sound understanding of population dynamics at biologically meaningful scales. Given management needs and available resources, there is undoubtedly a mismatch of spatial scale between the assessment (at both overall and regional levels) and the population biology of the target species. This is inevitable given the large stock area and the level of resources that would be needed to address this rigorously, but it is nevertheless important to consider the implications for the precision of assessment outputs and the ability to detect important population signals (recruitment and mortality). This could also be addressed through aspects of survey design, including the use of some fixed survey stations that could be followed over years. I suggest that the use of fixed survey stations would be a good use of survey effort that is directed towards the semi-random tows.

The issue of data ‘borrowing’ was briefly discussed at the review meeting. This relates to the use of data from adjacent years to fill data gaps for individual strata. This issue has been examined many times over recent years for both ocean quahog and surfclam surveys. There has certainly been effort to use statistically rigorous model-based imputation to fill these gaps, and I am unclear why this has so far proved unsuccessful. However, I recognize that borrowing is likely to have had very little impact on survey or assessment outputs, particularly given the very long time-scales over which population dynamic processes operate in such a long-lived species. The same applies to the aggregation of survey data over incomplete surveys in recent years (surveys split between years for both Georges Bank and the southern stock area, owing to insufficient time to complete within one survey season). Given plans for optimization of the survey for ocean quahogs, it is possible that data borrowing may become unnecessary. The same might apply if statistical techniques are applied to take account of spatial patterns (geostatistical approaches). Nevertheless, whilst data borrowing still occurs, I suggest that the application of model-based imputation techniques should not be dropped from the list of research recommendations.

TOR-3 Habitat characteristics

If possible, describe the relationship between habitat characteristics (benthic and pelagic) and ocean quahog distribution, and report on any changes in this relationship.

This TOR was met in full. Analyses previously reported at the SARC 61 surfclam review (NEFSC, 2016) showed that there had been an increase in co-occurrence of surfclams and ocean quahogs which was due to an extension of the deep water boundary of surfclam stocks rather than any change in distribution of ocean quahogs. Only in New Jersey was there any evidence of any change in ocean quahog distribution, this being a very modest increase in median depth of around 8 cm per year over 1982-2011.

SARC 63 reported on a new analysis of ocean quahog habitat using a random regression tree approach. This was applied to data for 1997-2011, treating Georges Bank separately from a reduced definition of a southern stock area (Southern New England and Long Island). The 1997-2011 period was deemed to represent current conditions and the use of sensor data to determine effective tow distances meant that accurate estimates of swept area were available for calculating catch numbers per unit area. A comprehensive set of habitat variables was compiled, including climatological, productivity, temperature, depth and bottom topography data. Although it is difficult to interpret model outputs in terms of the specifics of habitat dependencies, the models appeared to be very successful in predicting ocean quahog abundance in terms of habitat variables, with some corroboration between the analyses for northern and southern areas in terms of which variables were most important. It will be interesting to investigate whether the fine-scale patterns of spatial variability apparent from the model predictions are an artefact of the habitat data or representative of the actual scale of variability expected in the ocean quahog stock. There may also be some value in cross-referencing between the outcome of these analyses and the 'borrowed' values applied to fill gaps in survey strata in individual years.

Future work on this topic should address the issue of under-prediction of higher values, and also explore the value of models for projection of future scenarios. Whilst multi-factorial projection of correlated habitat variables is fraught with difficulties, there is nonetheless much value to be gained from attempting such an exercise, perhaps based on the outputs of integrated oceanographic and ecosystem models coupled with climate change predictions. Given the changes in stock distribution already apparent at the southern edges of ocean quahog distribution along the US east coast, it will be important to gain an understanding of what the scale and pattern of future changes might be – important both for forecasting the future of the fishery and for interpretation of future changes in terms of the relative roles of fishery and environmental/biological processes. The vulnerability of ocean quahog to future changes was briefly discussed during the review meeting. The consensus is that being in relatively deep water may buffer ocean quahogs from environmental change, but they may be more vulnerable to ocean acidification than changes in temperature (although surfclams are apparently robust to acidification). Any changes are likely to be very slow, and manifest through recruitment rather than survival processes, given the longevity of the species and the ability to be inactive during periods of unfavorable conditions (aestivation, involving deep burrowing).

TOR-4 Age determination and biological parameters

Evaluate age determination methods and available data for ocean quahogs to potentially estimate growth and recruitment. Review changes over time in biological parameters such as length, width, and condition.

This TOR was met in full. Age determination is difficult, based on interpretation of shell markings that can be very closely spaced. There is nevertheless a high degree of confidence that annual growth marks are determinable. Correspondence between long-term environmental records and growth events apparent in shell marks provides convincing corroboration of this. A number of different growth curves are available for ocean quahog, showing marked differences in overall shape. However, differences are less important at the sizes of 70 mm shell length and greater, representing ocean quahogs that have recruited to the fishery. There is also a great deal of variability of size at age; at 507 years old, the oldest individual seen was less than 70 mm shell length. The von Bertalanffy growth model, despite being the most commonly applied model, provides a poor description of both early growth patterns and the extent to which very old ocean quahogs continue to grow (200 year old ocean quahogs are still growing). The most successful growth model has been the Tanaka growth model, which is somewhat hard to interpret in terms of its parameters but provides a good description of the continuing nature of growth. It is not possible to define a Tanaka growth curve in the Stock Synthesis III (SS3) model used in the analytical stock assessment (see TOR-5); instead, a von Bertalanffy growth curve was defined with a large error to encompass the variability of size at the older ages.

The account of age and growth and the incorporation of appropriate data in the assessment was comprehensively and satisfactorily dealt with in the assessment report and review discussions. There is clearly scope for a closer examination of regional and other differences in productivity that may be apparent in size at age data, and consideration of the implications of this for spatial patterns in the stock and fishery. The main implications of age determination data for the assessment are: (i) that ocean quahog are extremely long-lived, providing a very low value for natural mortality of M=0.02; and (ii) that changes in length composition in the survey data are interpreted by the assessment model as a pulse of recruitment in the late 1990s. The first of these is certainly well founded, the second remains to be corroborated by future catches and surveys. Description of growth in the assessment model is probably adequate given currently available information, but it would clearly be more satisfactory if it was possible to define a Tanaka growth curve in the SS3 model. Perhaps more important, a perspective on future growth and productivity patterns is needed; this could be approached through analysis of historic growth patterns in relation to large scale variation in sea surface temperature and medium-term climate cycles such as the North Atlantic Oscillation.

TOR-5 Analytical stock assessment

Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR 4, as appropriate) and estimate their uncertainty. Include a *historical retrospective analysis to allow a comparison with previous assessment results and previous projections.*

This TOR was met in full. The benchmark assessment provided a transition from the previously applied KLAMZ delay-difference model to SS3 (Methot, 2015) which provides an integrated framework for inclusion of length composition data for the fishery and surveys alongside catch data and survey abundance indices. The time scale of population dynamic processes was defined through growth curves rather than incorporation of age data. Scaling information was provided through priors on survey catchability rather than fixed factors. The RD survey was split between trend and scale components, with only trend contributing to the model likelihood.

In common with the whole review panel, I endorse the use of the SS3 approach, the treatment of growth, separation of trend and scale components in the survey, use of priors on survey catchability, and exclusion of commercial LPUE as a source of information on stock trends. Particularly as this was a benchmark assessment, it would be useful to have an appendix to the assessment report that sets out the details of the equations used to describe population dynamics and the contributions of the different data sources to the overall model likelihood. Given the flexibility of the SS3 framework, reference to SS3 documentation does not adequately address this need for this specific application. Further, a narrative is needed to show the pathway of exploratory model runs towards the finally adopted model (BASE8). The likelihood profiles shown in the report and in the presentation at the meeting were very useful in supporting model choices, as was the inclusion of comprehensive sensitivity runs.

Although the SS3 model is very much to be preferred to the KLAMZ model which it supersedes, in one important respect it takes less account of stock structure. The latter model considered stocks on a regional basis, whereas the SS3 model simply recognized a difference between a northern and a southern stock area. This is, however, not likely to have any adverse impact on the overall outcomes. Both regional and larger scale divisions are very much larger than the scales at which population dynamic processes are likely to occur. It is not suggested that the analytical assessment model should attempt to capture these small-scale processes, and indeed this is never likely to be feasible in practice. Rather, analysis of finer scale patterns in survey data (and survey developments suggested above, including the use of fixed stations) is suggested to support interpretation of the larger scale assessment outcomes in terms of ocean quahog dynamics, thus providing a basis for examining risk in relation to any spatial mismatch. Analyses of survey data were used to provide empirical corroboration of the SS3 outcomes at the spatial scale of northern and southern stock areas, providing convincing evidence to confirm that fishing mortality rates are indeed very low.

Overall, assessment outputs were reassuringly unexciting, showing the stability of the stock and the lack of influence of fishing on stock dynamics, as would be expected for large stocks of a species of extreme longevity, exploited at very low levels. The one noticeable ‘feature’ in the model outcomes was a pulse of recruitment in the late 1990s, which the model ‘needed’ to account for features in the survey length compositions (relatively high frequencies at small sizes in the most recent RD survey samples, not evident in the MCD survey owing to lower selectivity at these sizes). In model terms, the resolution of this pattern in terms of a spike in recruitment is the most parsimonious and internally consistent solution. However, although plausible, the evidence base for this recruitment pulse is slender, and its reality or otherwise remains to be demonstrated in future survey and commercial catches. It will likely be a decade or more before this evidence accrues, but it is reassuring that the outcome of projections over a fifty-year time scale (see TOR-8) do not depend on the reality of this recruitment pulse (or, indeed, any recruitment at all) for the expected favorable status of the stock in relation to biological reference points. Responding to a request from the panel for additional analyses, a further model run was undertaken with the unusually high 1994 survey abundance removed. This demonstrated that the anomalous survey point (likely due to pump pressure) had no significant influence on the outcome of the assessment.

To conclude, the SS3 model provides a good basis for inferences about fishing mortality and stock biomass, and for taking forward into analyses of current and future stock status in relation to management criteria. This includes characterization of uncertainty in the analyses, which was based on the estimated Hessian matrix. As pointed out by Martin Cryer, given the Bayesian approach used, it would be preferable to use MCMC runs to characterize uncertainty; an attempt at this proved problematic during the review meeting, but application of MCMC in future assessments is certainly recommended. However, the lack of MCMC in the current assessment is not considered to have been a source of error in risk-based inferences about current and future stock status.

TOR-6 Biological reference points

State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

This TOR was met in full. MSY quantities are not directly estimable, given that there is no stock dynamic information (i.e., contrast in stock sizes) from which to estimate a stock recruitment relationship. Previously, the target fishing mortality was based on $F_{45\%}$ (the 45% being relative to virgin egg production) for a long-lived rockfish species. The value of this F_{MSY} proxy (0.022) was borrowed directly rather than being based on an analysis of relative spawning potential in ocean quahog. The target and threshold biomass values were previously taken as 0.5 and 0.4 respectively of the biomass estimated for 1978, taken to represent unfished biomass. By contrast, the recommended reference points are based on the outcome of a comprehensive series of management strategy evaluations (MSE). The MSE incorporated a wide range of assumptions about ocean quahog growth, recruitment and mortality and included uncertainty in both assessment and management implementation. It is worth noting that the methods used for the MSE are published in a peer-reviewed journal (Hennen, 2015), which provides a high degree of confidence in their scientific value as a basis for setting reference points in SARC 63. The newly proposed threshold fishing mortality (F_{MSY} proxy, value 0.019) was selected as a level that provided consistently high yield with few years of fishery closure. Rather than treating an individual year as representative of unfished biomass, a direct estimate of SSB_0 was available from the SS3 model (note change from fishable biomass to spawning stock biomass, stemming from the different biomass currencies used in the KLAMZ and SS3 models). Target and threshold SSB values were defined as $0.5*SSB_0$ and $0.4*SSB_0$ respectively.

This rigorous, MSE-based approach to providing reference points is a great improvement on the previous approach, and the panel strongly agreed with the adoption of both approach and values. The target fishing mortality is below the natural mortality value, which is a desirable property. Both biomass and fishing mortality reference points depend on scaling within the stock assessment for their absolute values, but the use of a ratio approach for stock status determination (see below) means that the assessment is robust to uncertainties about scale. The Panel noted that the target and threshold biomass values are close to one another, such that the scale of difference may be smaller than the scale of uncertainty. This is a point of mainly academic interest, however, since the approach of stock biomass towards either criterion (a) is highly unlikely over the next 50 years (as shown in stock projections), and (b) would provide greater insight into stock dynamics such that any necessary adjustment to these reference points could be made well before they were breached.

TOR-7 Stock status

Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to any new model or models developed for this peer review.

a. *When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.*
b. *Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-6).*

This TOR was met in full. Given uncertainties about scale in the assessment (driven largely by priors on survey catchability) status determination was treated in terms of ratios. Along with other Panel members, I endorse this approach which is robust to the uncertainty about scale. All approaches to status determination, using previous (KLAMZ) and current (SS3) models, and previous and recommended reference points, demonstrate convincingly that there is effectively zero probability that the stock is currently, or has ever been within the assessed period (1982-2016), either experiencing overfishing or in an overfished state. This analysis is supported by appropriate incorporation of uncertainty, and I have no doubt of the validity of the conclusions.

TOR-8 Stock projections

Develop approaches and apply them to conduct stock projections.

a. *Provide numerical annual projections (5 – 50 years) and the statistical distribution (e.g., probability density function) of the OFL (overfishing level), including model estimated and other uncertainties. Consider cases using nominal as well as potential levels of uncertainty in the model. Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).*
b. *Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.*
c. *Describe this stock's vulnerability (see "Clarification of Terms") to becoming overfished, and how this could affect the choice of ABC.*

This TOR was met in full. Projections were made from the terminal state of the SS3 model (2016) over a 50-year time horizon (2017-2066), over three harvest policies. These were fishing mortality at the threshold level (OFL catch), catch at the status quo level of 15,341 mt of meats, and catch at the quota level of 25,400 mt of meats. Status quo catch is probably the most likely scenario, whilst quota catch provides a likely upper bound on fishing pressure. Sensitivity runs were conducted using low and high natural mortality levels and recruitment levels, and removal of the entire catch from either the southern or northern stock area. An additional sensitivity run was undertaken during the SARC 63 meeting at the request of the Panel. This specified zero recruitment over the entire 50-year period.

I concur with the overall Panel view that the projections are correctly specified, take proper account of uncertainty taken forward from the SS3 model, and are properly precautionary in relation to scenarios for exploitation, recruitment and natural mortality. All projections show very low probability of the stock becoming overfished[1] over the next 50 years, even in the event that there is zero recruitment over this period. There is also effectively zero probability of overfishing occurring at status quo or quota catch levels, but, by definition, the threshold fishing mortality is central to the distribution of $F / F_{threshold}$ when exploitation is at the OFL level.

My only additional comment on the projections is that the strategy for allocating recruitment to southern and northern stock areas seems somewhat arbitrary – the proportion of recruitment in each area is taken to be the same as in the terminal year. In the future, I recommend that recruitment be allocated to northern and southern areas according to the distribution of proportions estimated for all years in the assessment. Clearly, this would have no impact on the outcome of the projections from this assessment, as even with zero recruitment there is very low (or zero) risk of the stock becoming overfished over the next 50 years.

It seems safe to conclude that the stock is not vulnerable to becoming overfished, even under the most precautionary scenarios. The overall assessment and recommended reference points thus provide a very robust basis for management.

TOR-9 Research recommendations

Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

This TOR was met in full. The Working Group considered 21 research recommendations from the previous assessment, of which nine were completed, one dropped as no longer relevant, seven were significantly progressed and four were outstanding. A further 14 new research recommendations were added by the Working Group, and during the review meeting a prioritized list was compiled by Larry Jacobson. As this list was not available for plenary discussion, I recommend that this be used as the basis for further discussion within the Working Group to set the agenda for future research in support of the ocean quahog assessment.

The range of research recommendations is wide, and I commend the Working Group for completion or significant progress against important research objectives relating to survey design and performance, age determination and biological parameters. I note that there are plans for research into spatial patterns, long-term population dynamics and its drivers, and consideration of ocean quahog stocks in an ecosystem context. I agree that these are priority areas. Of the new research recommendations, I note that number 13 is for considering a longer interval between benchmark assessments for ocean quahog. Given stable stock trends and the long-time scales expected for population dynamics of a very long-lived species, this seems a sensible suggestion. The same consideration might also apply to frequency of stock surveys, but before making decisions on either survey frequency or benchmark assessment intervals I recommend that the implications of both be explored within an MSE framework similar to

[1] N.B. There is an ambiguity in Figure 120 of the assessment document, as the x-axis is labelled as $SSB / SSB_{Threshold}$, whereas $SSB_{Threshold}$ is also labelled at a value of 0.5 on this axis. Depending on the interpretation of this axis, probabilities of being overfished are either effectively zero (if $SSB_{Threshold}$ is correctly located) or very low (if the axis label is correct).

that applied for deriving biological reference points. This might include weighing up the benefits of increased survey precision from higher intensity but lower frequency surveys against the cost of longer intervals without further survey updates. My own priorities for further research are included in my list of recommendations above (p.4).

Conclusions

SARC-63 successfully completed its TOR and provided a stock assessment, development of biological reference points and stock projections that will provide a sound scientific basis for management of the ocean quahog resource. The Working Group are to be commended for the rigor of their approach and for presenting the assessment in a clear and open manner. The ocean quahog fishery is remarkable for the longevity of its target species and for the very low fishing pressure, such that the fishery is unlikely to play much role in population dynamics with the consequence that fishery data are not informative on these dynamics. This provides a challenge for assessment, and I believe that the Working Group have provided a very sound stock assessment with effective use of available information. I believe that further insights into ocean quahog dynamics are likely to come from examination of patterns at much smaller spatial scales than currently considered, and that existing survey data together with future refinements of survey design and methodology are well placed to provide a basis for such examination.

Acknowledgments

I would like to thank the ocean quahog assessment working group for their hard work before and during the SARC-63 Review, and for their willingness to respond to questions and requests for analyses during the meeting. Particular thanks to Dan Hennen and Larry Jacobson for clear presentations and their openness and responsiveness during the meeting. Thanks also to Jim Weinberg and Sheena Steiner for excellent organization and arrangement of the meeting, and for getting material to the review team in good time. I am grateful to my fellow review panel members Martin Cryer, Anthony Hart and Ed Houde for being a pleasure to work with, and particularly to Ed for excellent chairmanship. Many thanks also to Roberto Koeneke and Manoj Shivlani for smooth and friendly administration of the contract and travel arrangements.

References

Hennen, D.R., 2015. How should be harvest an animal that can live for centuries? *North American Journal of Fisheries Management*, **35**, 512-527.

Methot, R.D., 2015. *User Manual for Stock Synthesis—Model Version 3.24s*. NOAA Fisheries Toolbox. 152 pp.

NEFSC, 2016. Stock Assessment of the Atlantic Surfclam. SAW/SARC 61. July 19-21, 2016, NOAA Fisheries, Northeast Fisheries Science Center. Woods Hole, MA. 474 pp.

APPENDIX 1: Bibliography of materials provided during the review meeting

Background documents:

Chute, A., Hennen, D., Russell, R. & Jacobson, L., 2013. Stock assessment update for ocean quahogs (*Arctica islandica*) through 2011. *NEFSC Reference Document 13-18.* 165 pp.

Harding, J.M., King, S.E., Powell, E.N. & Mann, R., 2008. Decadal trends in age structure and recruitment patterns of ocean quahogs *Arctica islandica* from the Mid-Atlantic Bight in relation to water temperature. *Journal of Shellfish Research*, **27**, 667-690.

Hennen, D.R., 2015. How should be harvest an animal that can live for centuries? *North American Journal of Fisheries Management*, **35**, 512-527.

Hennen, D.R., Jacobson, L.D. & Tang, J., 2012. Accuracy of the Patch model used to estimate density and capture efficiency in depletion experiments for sessile invertebrates and fish. *ICES Journal of Marine Science*, **69**, 240-249.

Kilada, R.W., Campana, S.E. & Roddick, D., 2007. Validated age, growth, and mortality estimates of the ocean quahog (*Arctica islandica*) in the western Atlantic. *ICES Journal of Marine Science*, **64**, 31-38.

Murawski, S.A., Ropes, J.W. & Serchuk, F.M., 1982. Growth of the ocean quahog, *Arctica islandica*, in the Middle Atlantic Bight. *Fishery Bulletin*, **80**, 21-34.

NEFSC, 2009a. Stock assessment for ocean quahogs (*Arctica islandica*). Report of the 48th Northeast Regional Stock Assessment Workshop (48th SAW). *NEFSC Reference Document 09-15.* 257 pp.

NEFSC, 2009b. Ocean quahog assessment summary for 2009. *48th SAW Assessment Summary Report. B. Ocean quahog.* 13 pp.

Rago, P.J., Weinberg, J.R. & Weidman, S., 2006. A spatial model to estimate gear efficiency and animal density from depletion experiments. *Canadian Journal of Fisheries and Aquatic Sciences*, **63**, 2377-2388.

Ridgway, I.D. & Richardson, C.A., 2011. *Arctica islandica*: the longest lived non colonial animal known to science. *Reviews in Fish Biology and Fisheries*, **21**, 297-310.

Thorarinsdóttir, G.G. & Jacobson, L.D., 2005. Fishery biology and biological reference points for management of ocean quahogs (*Arctica islandica*) off Iceland. *Fisheries Research*, **75**, 97-106.

Witbaard, R., 1996. Growth variations in *Arctica islandica* L. (Mollusca): a reflection of hydrography-related food supply. *ICES Journal of Marine Science*, **53**, 981-987.

Working papers:

Working Group, Stock Assessment Workshop (SAW 63) 2017. Stock Assessment Report of Ocean Quahog. SAW/SARC 63. February 21-23, 2017. NOAA Fisheries, Northeast Fisheries Science Center. Woods Hole, MA. 404p.

Working Group, Stock Assessment Workshop (SAW 63) 2017. Stock Assessment Summary Report of Ocean Quahog. SAW/SARC 63. February 21-23, 2017. NOAA Fisheries, Northeast Fisheries Science Center. Woods Hole, MA. 10p.

Working Group, Stock Assessment Workshop (SAW 63). 2017. Term of Reference 9 – Revised Research Recommendations. 2p.

Presentations:

Working Group, Ocean Quahog. 2017. Ocean Quahog Assessment 2017. PowerPoint presentation. 90 slides.

APPENDIX 2: Statement of Work

Statement of Work
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

63rd Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC)
Benchmark stock assessment for Ocean quahog

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards.
(http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).
Further information may be obtained from www.ciereviews.org.

Scope

The Northeast Regional Stock Assessment Review Committee (SARC) meeting is a formal, multiple-day meeting of stock assessment experts who serve as a panel to peer-review tabled stock assessments and models. The SARC peer review is the cornerstone of the Northeast Stock Assessment Workshop (SAW) process, which includes assessment development and report preparation (which is done by SAW Working Groups or ASMFC technical committees), assessment peer review (by the SARC), public presentations, and document publication. This review determines whether or not the scientific assessments are adequate to serve as a basis for developing fishery management advice. Results provide the scientific basis for fisheries within the jurisdiction of NOAA's Greater Atlantic Regional Fisheries Office (GARFO).

The purpose of this meeting will be to provide an external peer review of a benchmark stock assessment for **Ocean quahog**. The requirements for the peer review follow. This Statement of Work (SOW) also includes Appendix 1: TORs for the stock assessment, which are the responsibility of the analysts; Appendix 2: a draft meeting agenda; Appendix 3: Individual Independent Review Report Requirements; and Appendix 4: SARC Summary Report Requirements.

Requirements
NMFS requires three reviewers under this contract (i.e. subject to CIE standards for reviewers) to participate in the panel review. The SARC chair, who is in addition to the three reviewers, will be provided by either the New England or Mid-Atlantic Fishery Management Council's Science and Statistical Committee; although the SARC chair will be participating in this review, the chair's participation (i.e. labor and travel) is not covered by this contract.

Each reviewer will write an individual review report in accordance with the SOW, OMB Guidelines, and the TORs below. All TORs must be addressed in each reviewer's report. No more than one of the reviewers selected for this review is permitted to have served on a SARC panel that reviewed this same species in the past. The reviewers shall have working knowledge and recent experience in the application of modern fishery stock assessment models. Expertise should include forward projecting statistical catch-at-age models. Reviewers should also have experience in evaluating measures of model fit, identification, uncertainty, and forecasting.
Reviewers should have experience in development of Biological Reference Points (BRPs) that includes an appreciation for the varying quality and quantity of data available to support estimation of BRPs. For ocean quahogs (a bivalve), knowledge of long-lived, sedentary invertebrates would be useful.

Requirements for Reviewers

- Review the background materials and reports prior to the review meeting
- Attend and participate in the panel review meeting
    - The meeting will consist of presentations by NOAA and other scientists, stock assessment authors and others to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers
- Reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus.
- Each reviewer shall assist the SARC Chair with contributions to the SARC Summary Report
- Deliver individual Independent Review Reports to the Government according to the specified milestone dates

- This report should explain whether each stock assessment Term of Reference of the SAW was or was not completed successfully during the SARC meeting, using the criteria specified below in the “Requirements for SARC panel.”
- If any existing Biological Reference Points (BRP) or their proxies are considered inappropriate, the Independent Report should include recommendations and justification for suitable alternatives. If such alternatives cannot be identified, then the report should indicate that the existing BRPs are the best available at this time.
- During the meeting, additional questions that were not in the Terms of Reference but that are directly related to the assessments may be raised. Comments on these questions should be included in a separate section at the end of the Independent Report produced by each reviewer.
- The Independent Report can also be used to provide greater detail than the SARC Summary Report on specific stock assessment Terms of Reference or on additional questions raised during the meeting.

Requirements for SARC panel

- During the SARC meeting, the panel is to determine whether each stock assessment Term of Reference (TOR) of the SAW was or was not completed successfully. To make this determination, panelists should consider whether the work provides a scientifically credible basis for developing fishery management advice. Criteria to consider include: whether the data were adequate and used properly, the analyses and models were carried out correctly, and the conclusions are correct/reasonable. If alternative assessment models and model assumptions are presented, evaluate their strengths and weaknesses and then recommend which, if any, scientific approach should be adopted. Where possible, the SARC chair shall identify or facilitate agreement among the reviewers for each stock assessment TOR of the SAW.
- If the panel rejects any of the current BRP or BRP proxies (for B_{MSY} and F_{MSY} and MSY), the panel should explain why those particular BRPs or proxies are not suitable, and the panel should recommend suitable alternatives. If such alternatives cannot be identified, then the panel should indicate that the existing BRPs or BRP proxies are the best available at this time.
- Each reviewer shall complete the tasks in accordance with the SOW and Schedule of Milestones and Deliverables below.

Requirements for SARC chair and reviewers combined:

Review both the Assessment Report and the draft Assessment Summary Report. The draft Assessment Summary Report is reviewed and edited to assure that it is consistent with the outcome of the peer review, particularly statements that address stock status and assessment uncertainty.

The SARC Chair, with the assistance from the reviewers, will write the SARC Summary Report. Each reviewer and the chair will discuss whether they hold similar views on each stock assessment Term of Reference and whether their opinions can be summarized into a single conclusion for all or only for some of the Terms of Reference of the SAW. For terms where a similar view can be reached, the SARC Summary Report will contain a summary of such opinions. In cases where multiple and/or differing views exist on a given Term of Reference, the SARC Summary Report will note that there is no agreement and will specify - in a summary manner – what the different opinions are and the reason(s) for the difference in opinions.

The chair's objective during this SARC Summary Report development process will be to identify or facilitate the finding of an agreement rather than forcing the panel to reach an agreement. The chair will take the lead in editing and completing this report. The chair may express the chair's opinion on each Term of Reference of the SAW, either as part of the group opinion, or as a separate minority opinion. The SARC Summary Report will not be submitted, reviewed, or approved by the Contractor.

If any existing Biological Reference Points (BRP) or BRP proxies are considered inappropriate, the SARC Summary Report should include recommendations and justification for suitable alternatives. If such alternatives cannot be identified, then the report should indicate that the existing BRP proxies are the best available at this time.

Foreign National Security Clearance
When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, country of birth, country of citizenship, country of permanent residence, country of current residence, dual citizenship (yes, no), passport number, country of passport, travel dates.) to the NEFSC SAW Chair for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign- national-registration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance
The place of performance shall be at the contractor's facilities, and at the Northeast Fisheries Science Center in Woods Hole, Massachusetts.

Period of Performance
The period of performance shall be from the time of award through April 7, 2017. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

No later than January 17, 2017	Contractor sends reviewer contact information to the COR, who then sends this to the NMFS Project Contact
No later than February 7, 2017	NMFS Project Contact will provide reviewers the pre-review documents
Feb. 21 - 23, 2017	Each reviewer participates and conducts an independent peer review during the panel review meeting in Woods Hole, MA
February 23, 2017	SARC Chair and reviewers work at drafting reports during meeting at Woods Hole, MA, USA
March 9, 2017	Reviewers submit draft independent peer review reports to the contractor's technical team for review
March 9, 2017	Draft of SARC Summary Report, reviewed by all reviewers, due to the SARC Chair *
March 16, 2017	SARC Chair sends Final SARC Summary Report, approved by reviewers, to NMFS Project contact (i.e., SAW Chairman)
March 23, 2017	Contractor submits independent peer review reports to the COR and technical point of contact (POC)
March 30, 2017	The COR and/or technical POC distributes the final reports to the NMFS Project Contact and regional Center Director

* The SARC Summary Report will not be submitted to, reviewed, or approved by the Contractor.

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards:
(1) The reports shall be completed in accordance with the required formatting and content; (2) The reports shall address each TOR as specified; (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $20,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

Project Contacts

Dr. James Weinberg, NEFSC SAW Chair Northeast Fisheries Science Center
166 Water Street, Woods Hole, MA 02543 James.Weinberg@noaa.gov Phone: 508-495-2352

NEFSC Science Director Northeast Fisheries Science Center
166 Water St., Woods Hole, MA 02543
Phone: 508-495-2233

Appendix 1. *DRAFT Stock Assessment Terms of Reference for SAW/SARC-63*

(file vers.: 7/28/2016)

[NOTE: FINAL TORS WILL BE PROVIDED BEFORE THE PEER REVIEW]

The SARC Review Panel shall assess whether or not the SAW Working Group has reasonably and satisfactorily completed the following actions.

Ocean quahog

1. Estimate catch from all sources including landings and discards. Map the spatial and temporal distribution of landings, discards, and fishing effort, as appropriate. Characterize the uncertainty in these sources of data.

2. Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, length data, etc.). Use logbook data to investigate regional changes in LPUE, catch and effort. Characterize the uncertainty and any bias in these sources of data. Evaluate the spatial coverage, precision, and accuracy of the new clam survey.

3. If possible, describe the relationship between habitat characteristics (benthic and pelagic) and ocean quahog distribution, and report on any changes in this relationship.

4. Evaluate age determination methods and available data for ocean quahogs to potentially estimate growth and recruitment. Review changes over time in biological parameters such as length, width, and condition.

5. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR 4, as appropriate) and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections.

6. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

7. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to any new model or models developed for this peer review.
    a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.
    b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-6).

8. Develop approaches and apply them to conduct stock projections.

a. Provide numerical annual projections (5 – 50 years) and the statistical distribution (e.g., probability density function) of the OFL (overfishing level), including model estimated and other uncertainties. Consider cases using nominal as well as potential levels of uncertainty in the model. Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).
b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.
c. Describe this stock's vulnerability (see "Clarification of Terms") to becoming overfished, and how this could affect the choice of ABC.

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

Clarification of Terms
used in the Stock Assessment Terms of Reference

Guidance to SAW WG about "Number of Models to include in the Assessment Report":
In general, for any TOR in which one or more models are explored by the WG, give a detailed presentation of the "best" model, including inputs, outputs, diagnostics of model adequacy, and sensitivity analyses that evaluate robustness of model results to the assumptions. In less detail, describe other models that were evaluated by the WG and explain their strengths, weaknesses and results in relation to the "best" model. If selection of a "best" model is not possible, present alternative models in detail, and summarize the relative utility each model, including a comparison of results. It should be highlighted whether any models represent a minority opinion.

On "Acceptable Biological Catch" (DOC Nat. Stand. Guidel. Fed. Reg., v. 74, no. 11, 1-16-2009):

Acceptable biological catch (ABC) is a level of a stock or stock complex's annual catch that accounts for the scientific uncertainty in the estimate of Overfishing Limit (OFL) and any other scientific uncertainty…" *(p. 3208) [In other words, OFL ≥ ABC.]*

ABC for overfished stocks. For overfished stocks and stock complexes, a rebuilding ABC must be set to reflect the annual catch that is consistent with the schedule of fishing mortality rates in the rebuilding plan. *(p. 3209)*

NMFS expects that in most cases ABC will be reduced from OFL to reduce the probability that overfishing might occur in a year. (p. 3180)

ABC refers to a level of ''catch'' that is ''acceptable'' given the ''biological'' characteristics of the stock or stock complex. As such, Optimal Yield (OY) does not equate with ABC. The specification of OY is required to consider a variety of factors, including social and economic factors, and the protection of marine ecosystems, which are not part of the ABC concept. (p. 3189)

On "Vulnerability" (DOC Natl. Stand. Guidelines. Fed. Reg., v. 74, no. 11, 1-16-2009):

"Vulnerability. A stock's vulnerability is a combination of its productivity, which depends upon its life history characteristics, and its susceptibility to the fishery. Productivity refers to the capacity of the stock to produce Maximum Sustainable Yield (MSY) and to recover if the population is depleted, and susceptibility is the potential for the stock to be impacted by the fishery, which includes direct captures, as well as indirect impacts to the fishery (e.g., loss of habitat quality)." (p. 3205)

Participation among members of a Stock Assessment Working Group:

Anyone participating in SAW meetings that will be running or presenting results from an assessment model is expected to supply the source code, a compiled executable, an input file with the proposed configuration, and a detailed model description in advance of the model meeting. Source code for NOAA Toolbox programs is available on request. These measures allow transparency and a fair evaluation of differences that emerge between models.

Appendix 2. Draft Review Meeting Agenda

{Final Meeting agenda to be provided at time of award}

63rd Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC)
Benchmark stock assessment for A. Black sea bass and B. Witch flounder

February 21-23, 2017

Stephen H. Clark Conference Room – Northeast Fisheries Science Center Woods Hole, Massachusetts

DRAFT AGENDA*

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR

Tuesday, Feb. 21

10 – 10:30 AM
Welcome — **James Weinberg**, SAW Chair
Introduction — **Edward Houde,** SARC
Chair Agenda
Conduct of Meeting

10:30 – 12:30 PM Assessment Presentation (A. Ocean quahog)
Dan Hennen **TBD**

12:30 – 1:30 PM Lunch

1:30 – 3:30 PM Assessment Presentation (A. Ocean quahog)
Dan Hennen **TBD**

3:30 – 3:45 PM Break

3:45 – 5:45 PM SARC Discussion w/ Presenters (A. Ocean quahog)
Ed Houde , SARC Chair **TBD**

5:45 – 6 PM Public Comments

7 PM **(**Social Gathering**)**

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR

Wednesday, Feb. 22

9:00 – 10:45 Revisit with Presenters (A. Ocean quahog)
Ed Houde, SARC Chair **TBD**

10:45 - 11 Break

11 – 11:45 Revisit with Presenters (A. Ocean quahog)
Ed Houde , SARC Chair **TBD**

11:45 – Noon Public Comments

12 – 1:15 PM Lunch

1:15 – 4 Review/Edit Assessment Summary Report (A. Ocean quahog)
Ed Houde , SARC Chair **TBD**

4 – 4:15 PM Break

4:15 – 5:00 PM SARC Report writing

Thursday, Feb. 23

9:00 AM – 5:00 PM SARC Report writing

*All times are approximate, and may be changed at the discretion of the SARC chair. The meeting is open to the public; however, during the Report Writing sessions on July 20 and 21, we ask that the public refrain from engaging in discussion with the SARC.

Appendix 3. Individual Independent Peer Review Report Requirements

1. The independent peer review report shall be prefaced with an Executive Summary providing a concise summary of whether they accept or reject the work that they reviewed, with an explanation of their decision (strengths, weaknesses of the analyses, etc.).

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs. The independent report shall be an independent peer review, and shall not simply repeat the contents of the SARC Summary Report.

    a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including a concise summary of whether they accept or reject the work that they reviewed, and explain their decisions (strengths, weaknesses of the analyses, etc.), conclusions, and recommendations.

    b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.

    c. Reviewers should elaborate on any points raised in the SARC Summary Report that they believe might require further clarification.

    d. The report may include recommendations on how to improve future assessments.

3. The report shall include the following appendices:

    Appendix 1: Bibliography of materials provided for review
    Appendix 2: A copy of this Statement of Work
    Appendix 3: Panel membership or other pertinent information from the panel review meeting.

Appendix 4. SARC Summary Report Requirements

1. The main body of the report shall consist of an introduction prepared by the SARC chair that will include the background and a review of activities and comments on the appropriateness of the process in reaching the goals of the SARC. Following the introduction, for each assessment reviewed, the report should address whether or not each Term of Reference of the SAW Working Group was completed successfully. For each Term of Reference, the SARC Summary Report should state why that Term of Reference was or was not completed successfully.

   To make this determination, the SARC chair and reviewers should consider whether or not the work provides a scientifically credible basis for developing fishery management advice. If the reviewers and SARC chair do not reach an agreement on a Term of Reference, the report should explain why. It is permissible to express majority as well as minority opinions.

   The report may include recommendations on how to improve future assessments.

2. If any existing Biological Reference Points (BRPs) or BRP proxies are considered inappropriate, include recommendations and justification for alternatives. If such alternatives cannot be identified, then indicate that the existing BRPs or BRP proxies are the best available at this time.

3. The report shall also include the bibliography of all materials provided during the SAW, and relevant papers cited in the SARC Summary Report, along with a copy of the CIE Statement of Work.

   The report shall also include as a separate appendix the assessment Terms of Reference used for the SAW, including any changes to the Terms of Reference or specific topics/issues directly related to the assessments and requiring Panel advice.

APPENDIX 3: SARC 63 panel members and attendees

NAME	AFFILIATION	EMAIL
Ed Houde	U Maryland Center for Environmental Science	ehoude@umces.edu
Anthony Hart	Western Australian Fisheries	Anthony.Hart@fish.wa.gov.au
Mike Bell	Heriot-Watt University – Intl Centre for Island Tech	M.C.Bell@hw.ac.uk
Martin Cryer	Ministry for Primary Industries, Wellington	Martin.Cryer@mpi.govt.nz
Russ Brown	NEFSC	Russell.brown@noaa.gov
Jim Weinberg	NEFSC	james.weinberg@noaa.gov
Larry Jacobson	NEFSC	larry.jacobson@noaa.gov
Dan Hennen	NEFSC	Daniel.hennen@noaa.gov
Jessica Coakley	MAFMC	jcoakley@mafmc.org
Chris Legault	NEFSC	chris.legault@noaa.gov
Sheena Steiner	NEFSC	sheena.steiner@noaa.gov
Alicia Miller	NEFSC	alicia.miller@noaa.gov
Toni Chute	NEFSC	toni.chute@noaa.gov
Mark Terceiro	NEFSC	mark.terceiro@noaa.gov
José Montañez	MAFMC	jmontanez@mafmc.org
Joe Myers	Bumble Bee/Snow's Foods	joseph.myers@bumblebee.com
Tom Hoff	Wallace & Associates	tbhoff@verizon.net
Daphne Munroe	Rutgers University	dmunroe@hsrl.rutgers.edu
Tom Alspach	Sea Watch International	talspach@goeaston.net
Eric Powell	University of Southern Mississippi	eric.n.powell@usm.edu
Roger Mann	VIMS	rmann@vims.edu
D.H. Wallace	Wallace & Associates	DHWallace@aol.com
Doug Potts	NMFS/GARFO	douglas.potts@noaa.gov
Gary Shepherd	NEFSC	gary.shepherd@noaa.gov

APPENDIX 4: Agenda for the review meeting

63rd Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) Benchmark stock assessment for A. Ocean quahog

February 21-23, 2017

Stephen H. Clark Conference Room – Northeast Fisheries Science Center
Woods Hole, Massachusetts

AGENDA* (version: Feb. 15, 2017)

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR

Tuesday, Feb. 21

10 – 10:30 AM

Welcome — **James Weinberg**, SAW Chair
Introduction — **Edward Houde,** SARC Chair
Agenda
Conduct of Meeting

10:30 – 12:30 PM Assessment Presentation (A. Ocean quahog)
Dan Hennen **Toni Chute**

12:30 – 1:30 PM Lunch

1:30 – 3:30 PM Assessment Presentation (A. Ocean quahog)
Dan Hennen **Toni Chute**

3:30 – 3:45 PM Break

3:45 – 5:45 PM SARC Discussion w/ Presenters (A. Ocean quahog)
Ed Houde , SARC Chair **Toni Chute**

5:45 – 6 PM Public Comments

7 PM **(**Social Gathering**)**

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR

Wednesday, Feb. 22

9:00 – 10:45	Revisit with Presenters (A. Ocean quahog)	**Ed Houde,** SARC Chair	**Alicia Miller**
10:45 - 11	Break		
11 – 11:45	Revisit with Presenters (A. Ocean quahog)	**Ed Houde ,** SARC Chair	**Alicia Miller**
11:45 – Noon	Public Comments		
12 – 1:15 PM	Lunch		
1:15 – 4	Review/Edit Assessment Summary Report (A. Ocean quahog)	**Ed Houde ,** SARC Chair	**Alicia Miller**
4 – 4:15 PM	Break		
4:15 – 5:00 PM	SARC Report writing		

Thursday, Feb. 23

9:00 AM – 5:00 PM	SARC Report writing

*All times are approximate, and may be changed at the discretion of the SARC chair. The meeting is open to the public; however, during the Report Writing sessions on Feb. 22-23, we ask that the public refrain from engaging in discussion with the SARC.